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**AUTHOR** Garrison, H. Don  
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## ABSTRACT

Robots are machines designed to replace human labor. A fear of vast unemployment due to robots seems unfounded, however, since industrialization creates many more jobs and automation requires technologists to build, program, maintain, and operate sophisticated equipment. Robots possess an intelligence unit, a manipulator, and an end effector. Control is designed as either open loop (no verification of location) or closed loop (verification of location). The major uses of robots in industry are welding, machine loading, foundry, and pointing. The automobile industry, the largest user of robots, is actively pursuing automation of as many jobs as possible. The innovative manager can improve chances of successfully using robots by using a systematic approach. Three methods can determine the feasibility and correct type of robots for specific applications: (1) hire a reputable and experienced robot consultant, (2) select a robot manufacturing company, and (3) get the person most knowledgeable about the activities and processes within the company to analyze and evaluate possibilities. In a self-evaluation, a company should look at areas automation could benefit, including bottlenecks and prior and aft stations, excessive items in process, no-judgment jobs, hazardous or undesirable jobs, obsolete or worn-out equipment, and quality problems or excessive scrap. (YLB)

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## ROBOTS ARE TAKING OVER - WHO DOES WHAT

### INTRODUCTION

THE TERM "ROBOT" CONNOTES VARIOUS MEANINGS TO DIFFERENT PEOPLE. TO SOME IT MEANS THAT HUMAN LIKE MACHINES WILL ACCOMPLISH ALL THE DRUDGERY TYPE WORK. INDEED THERE IS SOME JUSTIFICATION TO THIS AS DOMESTIC JOBS THAT ROBOTS ARE DESIGNED FOR RANGE FROM VACUUMING FLOORS TO PREPARING MEALS, WALKING THE DOG AND BRINGING IN THE NEWSPAPER. OTHERS THINK OF ROBOTS AS INTELLIGENT MACHINES WITH THE CAPACITY TO COMMUNICATE, MANUFACTURE THEMSELVES AND TAKE OVER THE WORLD. THIS FANTASY IS PROBABLY DUE TO TELEVISION AND FICTION WRITERS THAT OFTEN PORTRAY ROBOTS IN SUCH A MANNER. SCIENTIST AND ASTRONOMERS VISUALIZE ROBOTS AS EXTREMELY COMPLEX ELECTRO-MECHANICAL SYSTEMS THAT CURRENTLY ASSIST IN REVEALING THE TRUTH ABOUT MYSTERIES OF THE UNIVERSE. LANDING MEN ON THE MOON AND PLACING VIKING ON MARS ARE EXAMPLES OF THE NEAR UNBELIEVABLE. PRECISION ROBOTS IN MEDICINE ARE MAKING STRONG CONTRIBUTIONS FOR MANKIND. IN OHIO, A ROBOT IS REPORTED TO HAVE PASSED AN EXAMINATION THAT WOULD ALLOW IT TO PRACTICE MEDICINE. CERTAINLY THERE IS A LOT OF HOPE AND PROMISE IN THE DEVELOPMENT OF MACHINES FOR MEDICINE AND SPACE.

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ENTREPRENEURS AND PRODUCTION MANAGERS FEEL THE DEVELOPMENT OF ROBOTS FOR THE MANUFACTURE OF GOODS IS VERY IMPORTANT. WITH APPROXIMATELY 28,000 OPERATING IN THE WORLD, ROBOTS HAVE DEMONSTRATED THERE ARE MANY JOBS THEY CAN DO WELL. WHILE THERE ARE MANY TASKS THAT ROBOTS DO WELL, IT IS IMPORTANT TO NOTE THEY ARE VERY CLUMSY WHEN COMPARED TO HUMANS. A ROBOT IS A MACHINE, INCAPABLE OF MAKING JUDGEMENT DECISIONS THAT HUMANS MAKE MANY TIMES DURING THE COURSE OF A DAY. SINCE ROBOTS VARY SO MUCH IN PURPOSE AS WELL AS APPEARANCE, IT IS DIFFICULT TO DESCRIBE THEIR PHYSICAL PROFILE, BUT THIS PAPER WILL USE THE ROBOT INSTITUTE OF AMERICA'S (RIA) DEFINITION. IT IS:

"A ROBOT IS A REPROGRAMMABLE MULTI-FUNCTIONAL MANIPULATOR DESIGNED TO MOVE MATERIAL, PARTS, TOOLS, OR SPECIALIZED DEVICES, THROUGH VARIABLE PROGRAMMED MOTIONS FOR THE PERFORMANCE OF A VARIETY OF TASKS".

ROBOTS ARE MANUFACTURED AS A "MACHINE". THEY ARE DESIGNED TO REPLACE HUMAN LABOR. SOME PEOPLE SEEM TO HAVE VISIONS OF MASSES OF ROBOTS OPERATING THROUGHOUT THE WORLD WHILE VAST NUMBERS OF PEOPLE ARE UNEMPLOYED. SINCE INDUSTRIALIZATION CREATED MANY MORE JOBS AND AUTOMATION REQUIRES TECHNOLOGIST TO BUILD, PROGRAM, MAINTAIN AND OPERATE SOPHISTICATED EQUIPMENT, THIS FEAR SEEMS UNFOUNDED - OR AT LEAST GROSSLY EXAGGERATED.

### ROBOT FUNDAMENTALS

ROBOTS, WHICH MANY FEEL ARE THE SOLUTION TO A GREAT NUMBER OF PROBLEMS, ARE MACHINES THAT POSSESS AN INTELLIGENCE UNIT, A MANIPULATOR AND AN END EFFECTOR. INTELLIGENCE IS PROVIDED BY A COMPUTER THAT SIGNALS FOR COORDINATE ACTION ON BASIC ASSEMBLIES, BUT MAY COORDINATE AND INTEGRATE SEVERAL MACHINES AND PROCESSES IN A SOPHISTICATED SYSTEM. MANIPULATOR IS THE BASE AND THE MOVEABLE ARMS ATTACHED TO IT. MOVEMENT OF THE MANIPULATOR MAY BE ELECTRICAL, HYDRAULIC, PNEUMATIC OR A COMBINATION OF THESE POWER SOURCES. END EFFECTORS ARE TOOLING THAT PROVIDES THE PHYSICAL CONNECTION BETWEEN MANIPULATOR AND MATERIAL, TOOL, OR MACHINE TO ACCOMPLISH WORK. CONTROL OF A ROBOT IS DESIGNED AS EITHER OPEN LOOP OR CLOSED LOOP. AN OPEN LOOP SYSTEM ALLOWS ACTUATORS TO OPERATE WITHOUT VERIFICATION OF LOCATION. A CLOSED LOOP SYSTEM PROVIDES FEEDBACK INFORMATION TO VERIFY LOCATION OF MANIPULATOR AT ALL TIMES. MOTIONS AND THE WORKING ENVELOPE OF THE MANIPULATOR CAN BE DESCRIBED ACCORDING TO COORDINATES. A RECTANGULAR COORDINATE ROBOT HAS 3 AXIS AND CAN MOVE VERTICAL, OR HORIZONTAL IN A RECTANGULAR ENVELOPE. (SEE FIGURE 1)

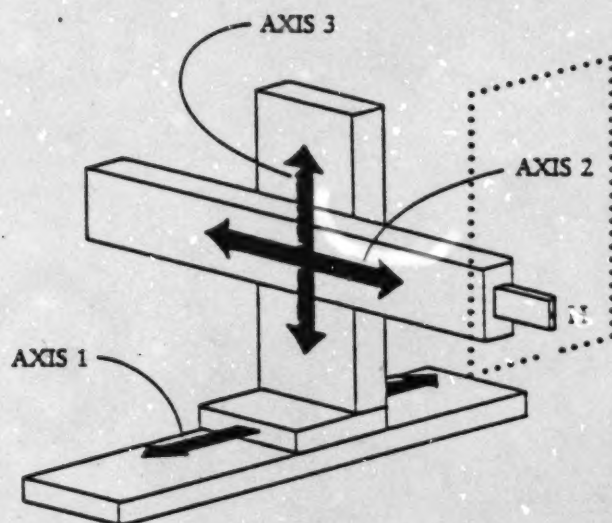


FIGURE 1: RECTANGULAR COORDINATE ROBOT  
(COURTESY PRENTICE-HALL INC.)

ANOTHER 3 AXIS UNIT IS THE CYLINDRICAL COORDINATE ROBOT.  
IT MOVES VERTICAL AND HORIZONTAL ON A ROTATING BASE.  
(SEE FIGURE 2)

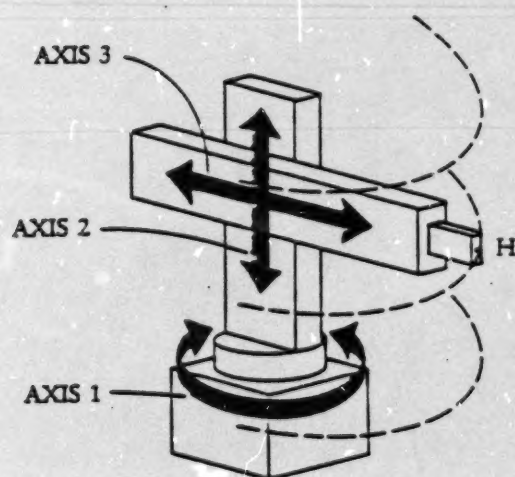


FIGURE 2: CYLINDRICAL COORDINATE ROBOT  
(COURTESY PRENTICE-HALL INC.)

A SPHERICAL COORDINATE ROBOT IS A 3 AXIS ROBOT THAT ROTATES ON THE BASE, ROCKS AROUND PIVOT IN AXIS 2 AND EXTENDS AND RETRACTS LINEARLY IN AXIS 3.

(SEE FIGURE 3)

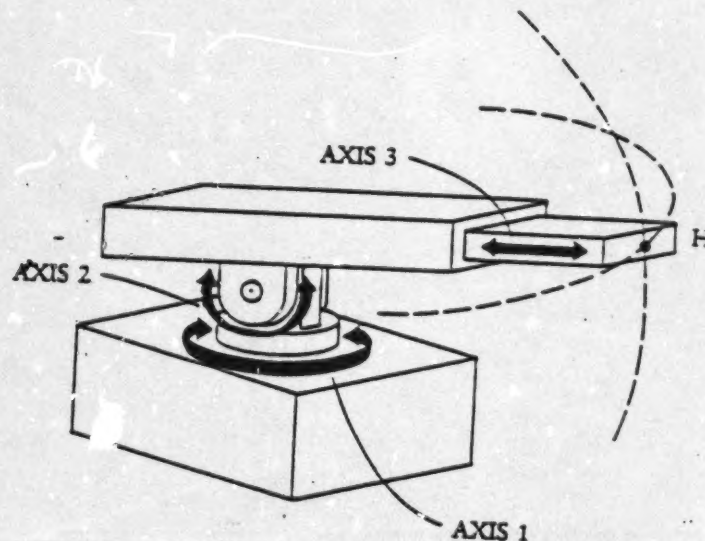


FIGURE 3: SPHERICAL COORDINATE ROBOT  
(COURTESY PRENTICE-HALL INC.)

ANTHROPOMORPHIC CHARACTERISTICS ARE PROVIDED WITH THE JOINTED ARM ROBOT. THE 3 AXIS ROBOT ROTATES ABOUT THE BASE, SHOULDER AND ELBOW. VERY COMPLEX MOTIONS CAN BE DEVELOPED WITH THE JOINTED ARM, ESPECIALLY IF MULTIPLE JOINTS ARE DESIGNED INTO THE UNIT.

(SEE FIGURE 4)

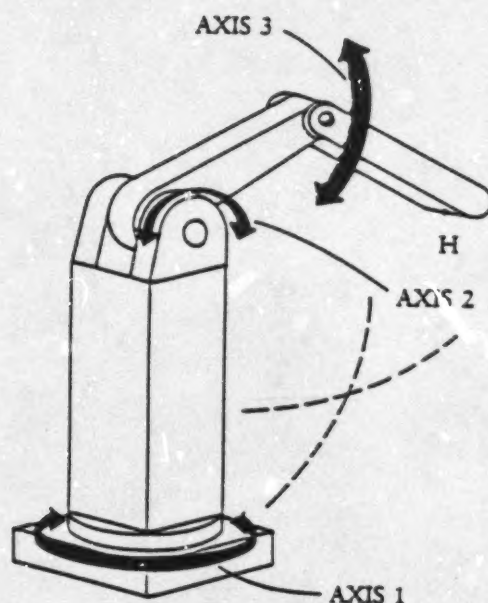


FIGURE 4: JOINTED ARM ROBOT  
(COURTESY PRENTICE-HALL INC.)

CINCINNATI MILACRON PRODUCES A JOINTED ARM ROBOT WITH 6 AXIS AND A REPEATABILITY OF  $\pm .025$  INCH. END EFFECTORS VARY ACCORDING TO THE SPECIFIC USE AND MAY BE ELECTRICAL, MECHANICAL, HYDRAULIC OR PNEUMATIC. SOME ARE SIMPLE SUCTION CUPS OR GRIPPING FINGERS WHILE OTHERS ARE VERY COMPLEX DEVICES WITH BUILT IN SENSORS AND MEMORY CIRCUITS. OPERATION OF MANY ROBOTS IS GETTING LESS AND LESS DIFFICULT AS COMPANIES DESIGN FOR USER FRIENDLY HARDWARE. WITH THE CONTROL SYSTEM ENGAGED IN THE TEACH MODE IT IS RELATIVELY EASY TO POSITION TOOLING IN THE DESIRED POSITION THEN ENERGIZE THE MEMORY CIRCUIT TO RETURN IT TO THAT POSITION AT THE PROPER TIME.

### ROBOTS IN INDUSTRY

THE MAJOR USES OF ROBOTS IN INDUSTRY ARE WELDING, MACHINE LOADING, FOUNDRY AND PAINTING. THE FOLLOWING TABLE INDICATES THE NUMBER AND PERCENT OF ROBOTS ACTIVE IN SPECIFIC JOBS IN THE UNITED STATES IN 1981.

| <u>APPLICATION</u>               | <u># OF ROBOTS</u> | <u>% OF TOTAL</u> |
|----------------------------------|--------------------|-------------------|
| WELDING                          | 1500               | 36                |
| MACHINE LOADING<br>AND UNLOADING | 850                | 20                |
| FOUNDRY                          | 840                | 20                |
| PAINTING                         | 540                | 13                |
| ASSEMBLY                         | 40                 | 1                 |
| OTHER                            | 400                | 10                |
|                                  | <hr/> 4170         | <hr/> 100         |

(ROBOTS INSTITUTE OF AMERICA 1982)

THE AUTOMOBILE INDUSTRY, WITH EVER INCREASING COMPETITION FROM FOREIGN SOURCES, IS ACTIVELY PURSUING AUTOMATION OF AS MANY JOBS AS POSSIBLE. AS SEEN IN THE FOLLOWING TABLE THE AUTOMOBILE INDUSTRY UTILIZES THE MOST ROBOTS AMONG THE INDUSTRIES IN THE UNITED STATES.

#### ROBOT UTILIZATION BY UNITED STATES INDUSTRIES IN RANK ORDER 1982 (RIA)

1. AUTOMOBILE
2. ELECTRIC MACHINERY
3. PLASTIC MOLDING
4. METAL WORKING
5. IRON AND STEEL

THE AUTOMOBILE INDUSTRY PROVIDES MANY JOBS IN WELDING THAT LEND THEMSELVES WELL TO ROBOT APPLICATION. ALTHOUGH PERCENTAGE OF WELDING ROBOTS IS DECREASING, IT IS IMPROVED TECHNOLOGY IN OTHER AREAS AND NOT A REDUCTION IN THE NUMBER OF ROBOT WELDERS IN USE. IN ALL PROBABILITY THE AUTOMOBILE INDUSTRY WILL CONTINUE AS THE LARGEST USER OF ROBOTS.

#### PRODUCTIVITY AND COMPETITIVENESS

AS SOME TASKS AND CONDITIONS LEND THEMSELVES WELL TO AUTOMATION, IT IS LOGICAL FOR INDUSTRY TO EVALUATE THE POSSIBILITY OF A MACHINE DOING THE OPERATIONS. IF A ROBOT CAN MAINTAIN PRODUCTION, AND QUALITY WHICH COULD INCREASE PROFITS THEN IT WOULD BEHOVE A COMPANY TO CONSIDER AUTOMATION AS A MEANS FOR IMPROVING ITS SELF. AN AWARENESS OF THE INTERNATIONAL ECONOMY AND PRODUCTIVITY CHANGES WILL HELP IN UNDERSTANDING THE EMPHASIS BEING PLACES ON COMPETITIVENESS. WHILE THE UNITED STATES ENJOYS THE HIGHEST PRODUCTIVITY RATE OF ALL THE INDUSTRIALIZED NATIONS, THEY ARE LAST IN MANUFACTURING PRODUCTIVITY GAIN. FROM 1973 TO 1979 FRANCE LED WITH A 5.1 PERCENT GROWTH IN PRODUCTIVITY AND THE UNITED STATES CHUGGED ALONG IN SIXTH PLACE WITH A 2.1 PERCENT IMPROVEMENT. (SEE ATTACHMENT 1)

DURING THE TIME BETWEEN 1978 AND 1980 THE UNITED STATES ACTUALLY SUFFERED APPROXIMATELY 1 PERCENT DECLINE. SOME ECONOMIST, PERHAPS JUSTIFIABLY SO, PLACED THE BLAME ON A CHANGE IN THE NATIONS WORK FORCE TO SERVICE AREAS. (SEE ATTACHMENT 2) TO GIVE PROPER CREDIT TO SOME INDUSTRIES IT IS NECESSARY TO NOTE THAT PRODUCTIVITY IN THE MANUFACTURE OF ELECTRONICS GREW AT A RATE WHICH REMAINED COMPETITIVE WITH ALL OTHER NATIONS. (SEE ATTACHMENT 3) IT IS APPARENT THAT THE INDUSTRIALIZED NATIONS OF THE FREE WORLD ARE COMPETING IN A TREMENDOUS STRUGGLE FOR THE WORLD MARKET.

TO MAINTAIN THE EXCELLENT STANDARD OF LIVING ENJOYED BY AVERAGE AMERICANS, PRODUCTIVITY MUST STAY IN LINE WITH WAGES. DURING THE 1970'S COMPENSATION PER MANHOUR GREW MUCH FASTER THAN OUTPUT PER MANHOUR. THIS AMONG OTHER THINGS RESULTED IN A PERIOD OF VERY HIGH INFLATION.

#### ROBOT IMPLEMENTATION

AFTER HEARING THE STORIES THAT ROBOTS WILL EITHER SAVE OR TAKE OVER THE WORLD, THE INNOVATIVE MANAGER CAN IMPROVE CHANCES OF SUCCESSFULLY UTILIZING ROBOTS BY USING A SYSTEMATIC APPROACH. THERE ARE THREE METHODS THAT CAN DETERMINE THE FEASIBILITY AND THE CORRECT TYPE OF ROBOTS FOR SPECIFIC APPLICATIONS.

THE FIRST IS TO HIRE A REPUTABLE AND EXPERIENCED ROBOT CONSULTANT. FOR A FEE THE CONSULTANTS WILL TOUR THE PLANT, REVIEW PRODUCTION RECORDS, ANALYZE THE TOTAL SYSTEM AND MAKE A REPORT. IF THERE ARE NO AUTOMATION PERSONNEL EMPLOYED, THE ENLIGHTENING REPORT IS USUALLY WELL WORTH THE INVESTMENT. A SECOND METHOD IS TO SELECT A ROBOT MANUFACTURING COMPANY. IT WILL PROBABLY BE NECESSARY TO CONVINCE THE MANAGER THERE IS A SINCERE INTEREST AND THAT SOME FUNDS ARE AVAILABLE TO AUTOMATE. A VISIT FROM ONE OF THE MARKETING REPRESENTATIVES CAN BE OF GREAT ASSISTANCE. OFTEN THEY WILL TAKE TIME TO ESCORT PROSPECTIVE BUYERS TO OTHER COMPANIES USING ROBOTS THAT ACCOMPLISH SIMILAR ACTIVITIES. IT IS GOOD TO REMEMBER THE ROBOT COMPANY IS IN BUSINESS TO SELL ITS OWN ROBOTS. THE POSSIBILITY EXISTS THAT THEY MIGHT ATTEMPT TO SELL AN EXPENSIVE UNIT WHEN ONE OF LOWER VALUE COULD DO AN EQUAL JOB. A THIRD METHOD TO DETERMINING NEED IN AN ORGANIZATION IS TO GET THE PERSON THAT IS MOST KNOWLEDGEABLE ABOUT THE ACTIVITIES AND PROCESSES WITHIN THE COMPANY TO ANALYZE AND EVALUATE POSSIBILITIES. THIS IS PROBABLY THE MOST DIFFICULT, BUT IT DOES PROVIDE THE ADVANTAGE OF CONSIDERABLE INTERNAL INPUT. THIS COULD REALLY BE VALUABLE IN HUMAN RELATIONS WITH THE WORK FORCE. A DISADVANTAGE IS OVER-FAMILIARITY. THIS CAN BE A HINDRANCE, BECAUSE IT IS OFTEN DIFFICULT TO SEE A BETTER

OR DIFFERENT WAY TO DO A JOB AFTER ACCOMPLISHING IT IN A GIVEN MANNER FOR SEVERAL MONTHS OR YEARS.

WITHHOLDING JUDGEMENT UNTIL ALL INFORMATION HAS BEEN TALLIED AND ANALYZED IS VERY IMPORTANT. A STRONG CASE CAN BE MADE NOT TO AUTOMATE AT MANY STATIONS, BUT IT IS THE WISE INVESTIGATOR THAT POSTPONES DECISIONS UNTIL THE ENTIRE EVALUATION IS COMPLETE. PREJUDICIAL DECISIONS ARE SELF DEFEATING AND MUST BE AVOIDED.

THERE ARE SEVERAL THINGS TO LOOK FOR IF A COMPANY DECIDES TO DO ITS OWN EVALUATION. AN AREA WITH AN EXCESSIVE NUMBER OF PEOPLE, MAY BE A BOTTLE NECK THAT AUTOMATION COULD BENEFIT. LOOK NOT ONLY AT THE LABOR INTENSIVE POINT, BUT ALSO PRIOR AND AFT STATIONS.

EXCESSIVE ITEMS IN-PROCESS IS ANOTHER POSSIBLE PLACE THAT ROBOTS CAN OPERATE WELL. IN-PROCESS ITEMS ARE COSTLY DUE TO FLOOR SPACE NEEDED, MATERIAL INVESTMENT AND LABOR COSTS TO MANAGE ADMINISTRATIVELY. IN SUCH AN AREA REMEMBER THE WORKPLACE CAN BE SET UP IN FOUR WAYS:

- . WORK ARRANGED AROUND THE ROBOT,
- . WORK BROUGHT TO THE ROBOT,
- . WORK TRAVELS PAST THE ROBOT, AND
- . ROBOT TRAVELS TO THE WORK.

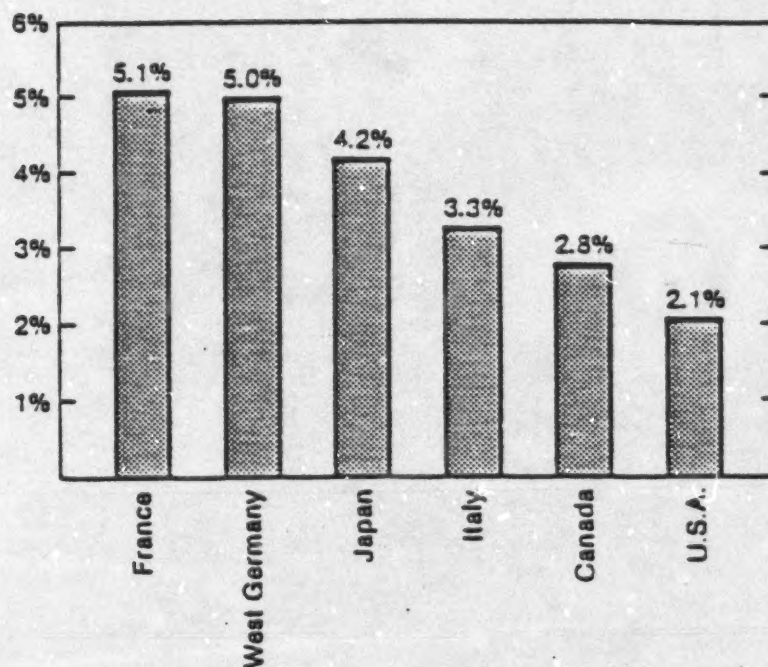
NO JUDGEMENT JOBS ARE PRIME AREAS FOR POSSIBLE UPGRADING. EMPLOYEES THAT ARE DOING SUCH MEANIAL JOBS AS LOADING AND UNLOADING MACHINES, PALLETIZING UNITS OR DOING UNCHANGING REPETITIVE TASKS CAN PROBABLY BE REPLACED WITH MACHINERS.

PRIOR TO MAKING SUCH A MOVE THESE PEOPLE NEED TO BE INFORMED HOW THE CHANGE WILL BENEFIT THEM. REASSIGNMENT TO A MORE CHALLENGING JOB OR RETRAINING NOT ONLY MAY IMPROVE EMPLOYEE MORAL BUT ALSO CAN IMPROVE COMPANY PROFITS. HAZARDOUS OR UNDESIRABLE JOBS ARE PRIME AREAS FOR CLOSE SCRUTINY.

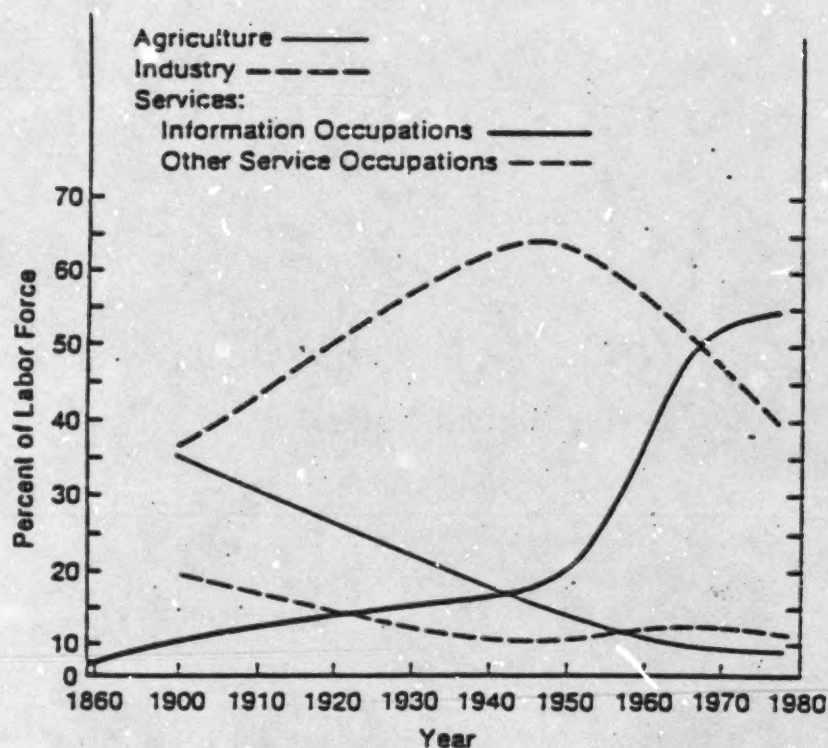
CLOTHING OR APPARATUS NECESSARY TO FUNCTION IN A HAZARDOUS ENVIRONMENT IS EXPENSIVE AND MACHINERY MAY BE ABLE TO DO THE JOB WITHOUT NEEDLESSLY ENDANGERING PERSONNEL.

OBSOLETE OR WORN OUT EQUIPMENT THAT NEEDS REPLACING IS ANOTHER PLACE TO ANALYZE THOROUGHLY. OFTEN AUTOMATED MACHINERY CAN DO THE JOB BETTER AND FASTER WITH LITTLE IF ANY MORE CAPITAL OUTLAY. THE LAST ITEM IS QUALITY PROBLEMS OR EXCESSIVE SCRAP. IF THERE SEEMS TO BE A LARGE NUMBER OF REJECTS IT IS VERY POSSIBLE THAT THE REGIMENTED OPERATION NECESSARY FOR A ROBOT CAN PROVE BENEFICIAL.

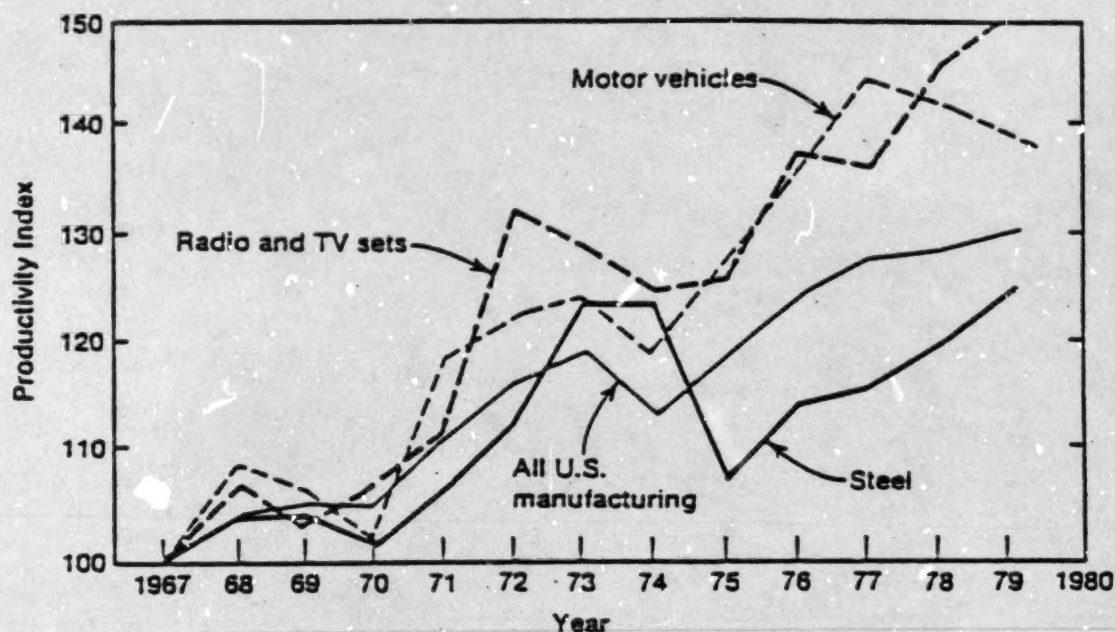
THIS PAPER HAS DISCUSSED ROBOTS IN A VERY BROAD SENSE. IF SOMEONE IS STILL CONSIDERING INSTALLING ROBOTS IT WOULD BE A GOOD IDEA TO REMEMBER TO KEEP IT SIMPLE, START WITH A MODERATELY SOPHISTICATED UNIT TO LEARN, TRAIN ALL PERSONNEL THAT ARE INVOLVED, AND PROVIDE AN ALTERNATE PATH TO MAINTAIN PRODUCTION DURING ANY TEMPORARY OR UNFORSEEN ROBOT INTERRUPTIONS.



ATTACHMENT 1: AVERAGE MANUFACTURING PRODUCTIVITY GROWTH 1973-79. THE U.S. LAGS BEHIND OTHER INDUSTRIALIZED COUNTRIES. SOURCE: U.S. DEPARTMENT OF LABOR, BUREAU OF LABOR STATISTICS. (COURTESY PRENTICE-HALL INC.)



ATTACHMENT 2: THE PERCENTAGE OF U.S. WORKERS IN SERVICE-RELATED INDUSTRIES HAS BEEN INCREASING STEADILY SINCE 1960, WITH THE MOST DRAMATIC INCREASE BEGINNING IN THE 1950's.  
SOURCE: U.S. CONGRESSIONAL COMMITTEE ON HOUSE ADMINISTRATION.  
(COURTESY PRENTICE-HALL INC.)



ATTACHMENT 3: BUREAU OF LABOR STATISTICS PRODUCTIVITY INDEXES (PHYSICAL OUTPUT PER HOUR - ALL EMPLOYEES, 1967 = 100). SOURCE: PRODUCTIVITY INDEXES FOR SELECTED INDUSTRIES (WASHINGTON DC: BUREAU OF LABOR STATISTICS). (COURTESY PRENTICE-HALL INC.)

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